Improvements to the Watershed Modeling System (WMS)

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Introduction

Researchers from the Environmental Modeling Research Laboratory (EMRL) at Brigham Young University and the US Army Corps of Engineers' Coastal and Hydraulics Laboratory (CHL-ERDC-USACE) jointly develop the Watershed Modeling System (WMS). This system acts as a pre- and post-processor for more than 10 separate hydrologic and hydraulic computational modeling programs. WMS is licensed freely for use throughout the Corps of Engineers and has been used in a multitude of hydrologic and hydraulic studies. Version 7.0 of WMS is slated for release this summer. This presentation will document some of the enhancements and improvements implemented in this latest version.

Enhancements include the inclusion of the ArcGIS software from ESRI directly within the program. This allows WMS to access and display all GIS data types supported by ArcGIS. Additionally, all data layers, including the GIS data, the traditional map module coverages, TINs, DEMs, and models are now managed in a hierarchical data tree window. New modeling tools include a wide variety of DEM and TIN editing tools that filter, edit, and prepare digital terrain models for use with the multitude of hydrologic and hydraulic modeling programs. A new interface has been developed for the HEC-RAS riverine computational program and WMS continues to support the latest enhancements to the GSSHA spatial hydrologic model developed jointly by Dr. Fred Ogden from the University of Connecticut and Dr. Chuck Downer at CHL-ERDC-USACE. GSSHA improvements include better support for channel routing, storage routing through lakes, reservoirs, and along dikes or levees (obstructions) in the overland flow regions. Improved terrain editing tools simplifies the process of developing a stable overland flow model and enhanced results management and visualization aids in calibration and model assessment. Each of these and additional enhancements will be discussed in detail in the following sections.

Data module and Delineation module replace TIN and DEM modules

Version 7.0 includes a new Terrain Data module that allows the user to import, create, edit, and preprocess all digital terrain data, whether it is a TIN or DEM. The Delineation module is then used to delineate a watershed from either a TIN or a DEM. Several additional tools have been added as well. These tools allow users to directly edit of the elevation values for both TINs and

DEMs watershed delineation as well as for hydraulic modeling using the new HEC-RAS interface tools. Improvements to WMS 7.0 in the new Terrain Data module include:

- the ability to edit DEM elevations. Feature arcs can now used in the DEM elevation-editing environment to adjust DEM elevations. This could be used to "carve" out a canal or other small stream not accurately represented by the original elevations of a DEM. Highway embankment or other such structures that may act as a levee and alter watershed or flood delineation can also be inserted through this tool.
- much faster and more robust TIN triangulation and processing. Improvements include a new triangulation algorithm and the ability to generate more accurate TINs from very large DEMs.
- tools to thin LIDAR and other dense triangulation sets are provided.
- tools to extract the significant elevation points from DEMs have been implemented.
- contours from TINs or DEMs can now be exported as feature lines then as shape files for sharing in a GIS.

Data Tree Window

A new user interface object implemented in WMS 7.0 is a data tree window that can be used to navigate and set properties for WMS data objects. The data tree window is dockable and can be moved to any part of the WMS application. The data tree window allows the user to quickly find and manipulate model input data as well as multiple solution sets associated with a single computational model. This feature is shown in Figure 1

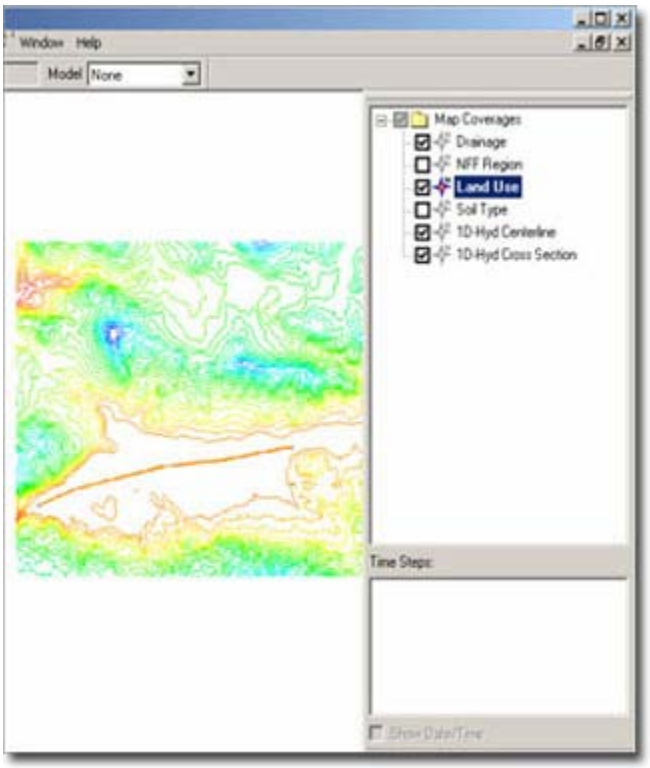


Figure 1 – Dockable data tree window for easy data manipulation.

This window is extremely useful for managing coverages in the map module (or GIS data layers in the new GIS module) because it allows the user to quickly set visibility by setting the check mark on or off, and access display and other object related parameters by right-clicking the object to bring up an object specific menu. Figure 2 shows the results of right-clicking on one of the data layers in the data tree window.

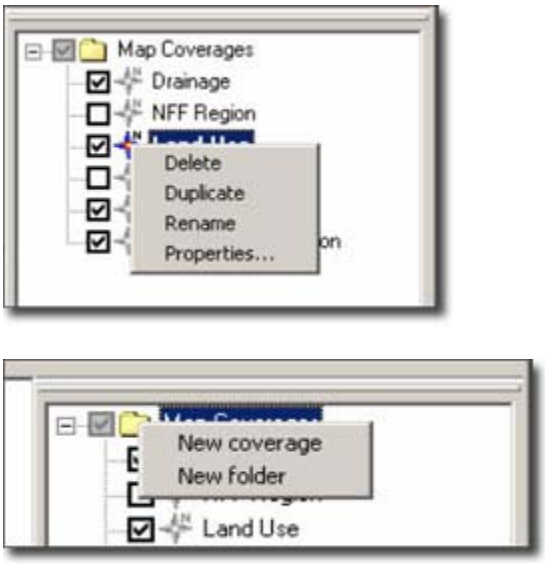


Figure 2 – Data Tree Window actions.

The active coverage, GIS layer, or TIN can be set by clicking on it in the data tree window (it will become highlighted or colored whereas inactive coverages are dimmed). The user can also control the display order of coverages by dragging them higher (display sooner) or lower (display later) in the data tree. New coverages or TINs are created by right-clicking the top folder in the tree. This functionality is similar to how GIS systems works and was implemented to not only increase usability by those familiar with GIS systems but also to make the data modules more compatible with the new GIS module.

GIS Module

Past versions WMS have interfaced with GIS data primarily through shape files. Because WMS is not a GIS management system itself, but a computational modeling system, manipulation of GIS specific data (in particular land use and soils layers) has been limited. The ability to process large files, clip out regions of interest, or join additional soils database tables to extract important information is critical for the successful modeling effort. Furthermore, being able to visualize modeling results directly within a GIS system with other ancillary GIS data is desirable. Version 7.0 of WMS has undergone significant changes in the way that GIS data can be read, displayed, and used for developing hydrologic modeling parameters. The tools for reading, displaying, and converting GIS data have been separated from the Map module to form a new GIS Module.

The GIS module has two modes of operation. The first mode is available when an active license for ArcView (ArcEdior, or ArcInfo as well) version 8.0 or higher is found. The user can enable the use of ArcObjects within WMS which essentially allows you to run ArcView within WMS. This enables WMS to incorporate ESRI technology to open any GIS data file that ArcView can open. This includes images, ESRI formatted coverages, ESRI formatted GRIDs, ESRI formatted TINs, CAD files, geodatabases, and shape files. ArcObjects functions also allow the control of display, table viewing and joining, and many other ArcView capabilities within WMS. Figure 3 shows the new GIS module working directly with ArcObjects technology.

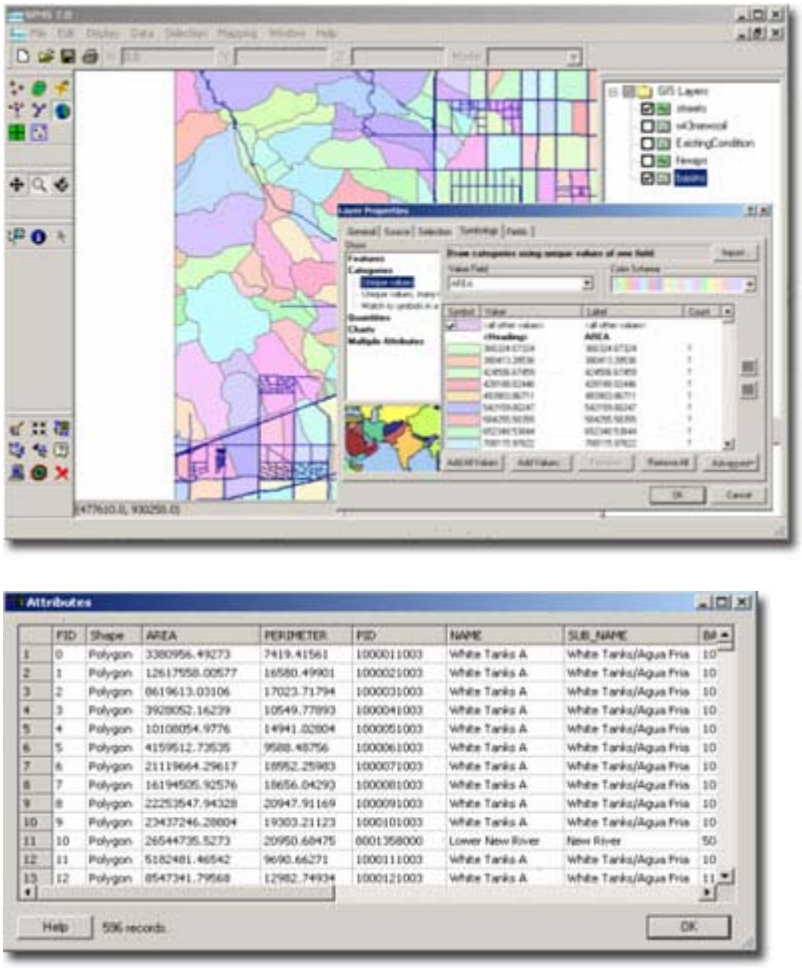


Figure 3 – The new GIS module works directly with ESRI ArcView 8.x technology. This allows WMS to import any GIS data type supported by ESRI. All visualization tools from ArcView are also supported.

The second mode of operation occurs when no active license for ArcView 8.0 or higher is found. In this case the GIS module will allow the user to read in and display shape files as GIS layers. Only a portion of the capability for displaying data, tables, and other GIS functions are available with shape files, but unlike previous versions of WMS large shape files are more efficiently read and displayed as initially the shape file is not converted to a WMS coverage.

A key feature for both operational modes of the new GIS module is that individual features (points, lines, polygons) can be selected from the GIS layer. Only these selected features are

converted to feature objects for use in the WMS map module. This allows you to read in a large soils data layer, select the soils that cover a specific watershed, and then only convert the small subset of soils into a WMS coverage as shown in Figure 4.

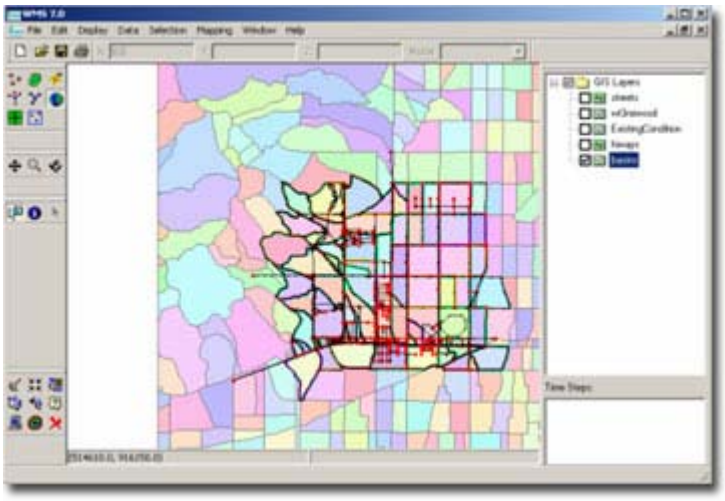
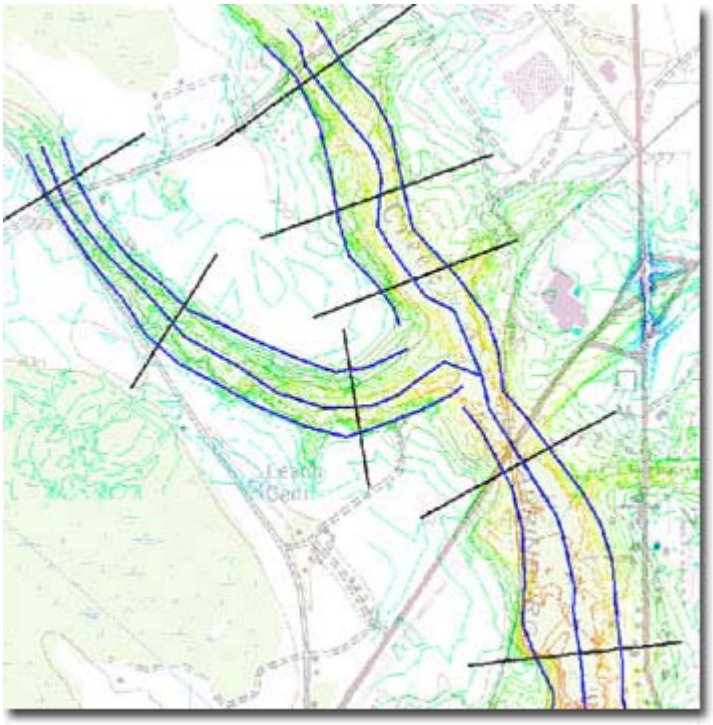


Figure 4 – The new GIS module allows a small subsection of the available GIS coverage to be converted into a WMS map layer for use in hydrologic modeling.

Previous versions required this kind of manipulation to be done with ArcView or some other GIS tools, but now GIS data can be managed completely within WMS using the new GIS module. If you own a license of ArcView then you will have additional access to file formats and other advanced display capabilities.

Hydraulic Modeling module

The addition of tools for hydraulics modeling of streams and rivers is perhaps the most anticipated portion of the WMS 7.0 release. Support for HEC-RAS (steady flow analysis), UNET (unsteady flow analysis), and BRI-STARS (flow and sediment transport analysis) have been placed in the new Hydraulics Module of WMS. This module allows the user to cut cross sections and designate thalweg/bank locations using features objects and digital terrain data. The cross sections can be edited using the new Cross Section Editor and stored in a cross section database. These new tools are shown in Figure 5.



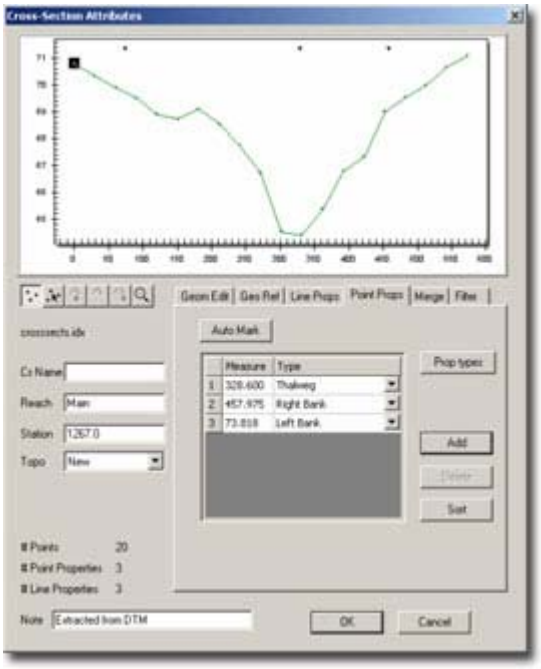


Figure 5 – New hydrologic modeling tools including river feature and cross section editor are now included in WMS 7.0.

The new tools allow material properties, such as Manning's n, to be assigned by overlaying GIS land use data. Flow input can input directly or can be tied to hydrologic model results. This effectively makes WMS a regional scale analysis system because upstream hydrologic modeling results can be fed directly into downstream hydraulic models.

WMS can also set up data files in native HEC-RAS format for use with the HEC-RAS interface. UNET or BRI-STARS simulation can be run directly from WMS. Results from any of these models can then be used in WMS for flood plain delineation and flood mapping.

Hydrologic and Hydraulic Model Linkages and Stochastic Modeling

Because HEC-RAS now has a native implementation within WMS, loosely coupled analysis systems can be developed. Modeling results from the lumped parameter model HEC-1 as well as the 2D spatial hydrologic model GSSHA can be linked to a HEC-RAS model to evaluate the impact of upland changes on riverine flows. Figure 6 through Figure 8 illustrate the new model linkage.

Figure 6 – HEC-1 Hydrologic Model Defined from a DEM.

Figure 7 – HEC-RAS Hydraulic Model Defined from a TIN Using Cross Section and Centerline Coverages.

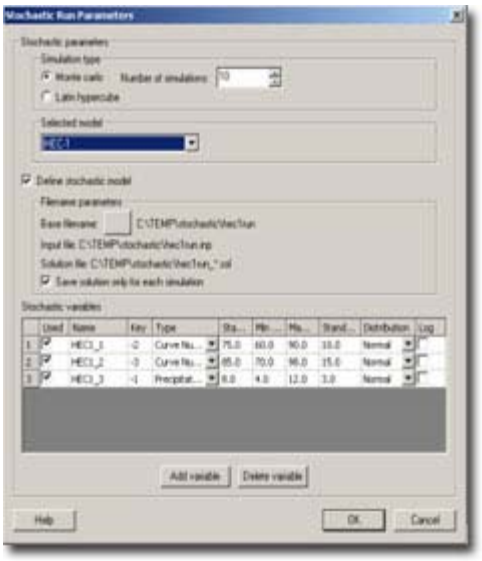


Figure 8 – Model linkage dialog box allowing output values from hydrologic models to be directly applied to the downstream hydraulic model.

Stochastic Run Parameters for HEC-1 Model.

One of the more significant results of the model linkage tools now in WMS 7.0 is the ability to evaluate how the uncertainty in parameter values can impact floodplains. This is done by using the new Stochastic simulation tool. This tool can be used to adjust certain modeling parameters within a range of probable values and then running the linked simulations. For example a HEC-1 hydrologic model can be used to determine the peak flow (steady state analysis) or flow hydrograph (unsteady analysis) as input to the HEC-RAS model. Rainfall and/or Curve Number could be varied over a series of simulations (10 to 100 or more) so that the entire range of probable values can be simulated. Further Manning's roughness values could be varied for the HEC-RAS model to account for uncertainties in these parameters. The results (water surface elevation) of the linked simulation are used with the flood plain delineation tools in WMS to determine a flood plain boundary for each set of linked simulations. After running the desired number of simulations, a probabilistic flood plain boundary is generated. The probabilistic flood plain boundary identifies regions flooded by 100% of the modeling results, 50% of the modeling results, 10% of the modeling results, etc. Such a flood plain is more realistic because it better accounts for the uncertainty in the parameters used to develop the flood plain.

The stochastic modeling can also be done separately for a HEC-1 or HEC-RAS model in order to compute a "range" of peak flows (hydrographs) or water surface elevations for a given model. Stochastic simulations for a model are defined by entering a unique negative value (-1 for first parameter, -2 for second, etc.) for a parameter within HEC-1 that you wish to determine a series of valid values within a defined range. The Stochastic Run Parameters dialog can then be used to set the number of simulation and simulation type as well as the starting, min, max, and std deviation for each parameter in the model with a defined key. In the example above Curve Number (CN) for two different basins and Precipitation for the HEC-1 model have been defined as stochastic variables. Ten total simulations will be run choosing parameters from within the defined ranges using a Monte Carlo simulation for choosing the values. In the initial release of

7.0 only CN and Precipitation will be possible parameters for HEC-1 models and Manning's roughness for HEC-RAS models. Future versions will likely add to this list. Figure 9 and Figure 10 show how the uncertainty analysis tools can be used for stochastic flood plain delineation and stochastic flow evaluation.

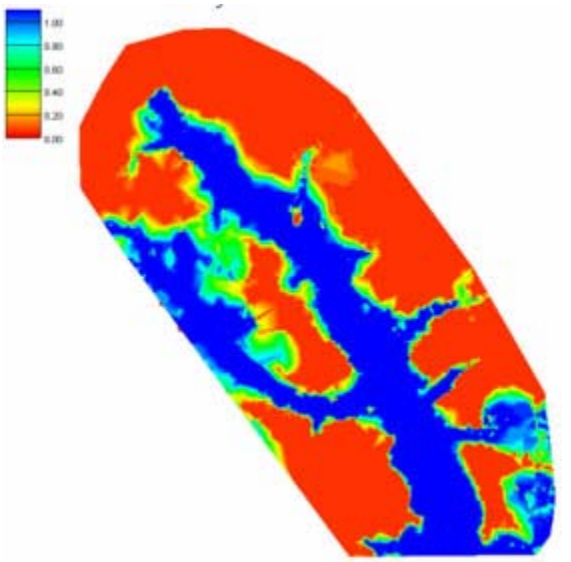


Figure 9 – Probabilistic Flood Plain generated using the stochastic modeling tool in conjunction with the flood plain analysis tool and the model linkage tool.

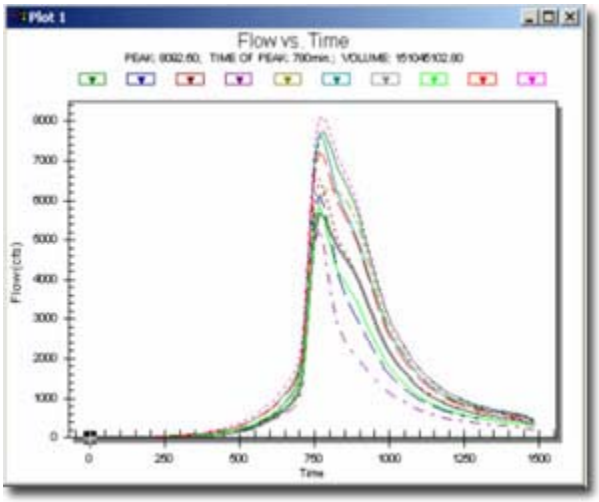


Figure 10 – Computed Hydrographs from a Stochastic HEC-1 Simulation.

Storm Drain interface

WMS version 7.0 has the capability of doing storm drain analysis using the analysis code distributed by the Federal Highway Administration as part of their HYDRAIN program. In WMS this is called Storm Drain, but it uses the HYDRA program as distributed by the FHWA to do the calculations. Models can be set up using a GIS layer to represent the pipe network and junctions. It can be linked with a surface drainage layer developed in WMS and then either rational method

or hydrographic (using hydrographs computed using any of the WMS-supported hydrologic models) analysis options. The Storm Drain program in WMS supports all of the different inlet conditions outlined in the FHWA Hydrologic Engineering Circular (HEC) 22 manual. Figure 11 shows the routing points designated in the Storm Drain program.

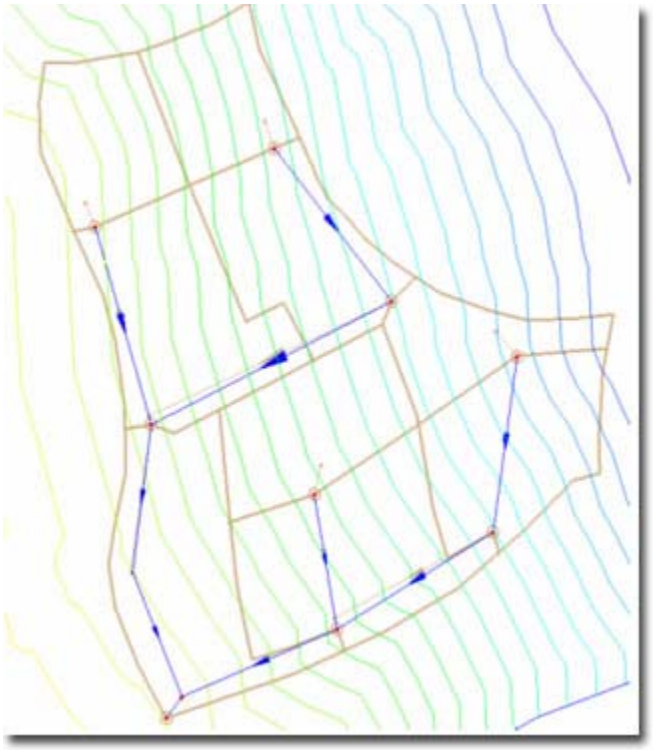


Figure 11 – Routing points designated in the Storm Drain program.

Basic Hydrologic Modeling Interfaces now Public Domain

For version 7.0 of WMS there will no longer be a Demo version that allows you to use the full capabilities of WMS without the possibility of saving or printing. However, the basic tree (schematic) tools for building hydrologic models, along with the graphical user interface to the hydrologic models like HEC-1, TR-20, NFF, etc. will no longer require a paid license to access. User's must still register their copies of WMS with EMS-I in order to activate the hydrologic models, but no licensing fee will be required to set up, save, run, and view results for any of the hydrologic modeling tools.

Miscellaneous

Additional enhancements to WMS are listed below.

- All files are opened using the File-Open command and saved using File-Save (or Save As). Previous versions used "Open" for WMS file types and "Import" for files not native to WMS (like DEMs, TIFF images, DXF, etc.). Similarly WMS files were saved using "Save" and other file types using "Export".

- The tool bar, tree window, and other elements of the user interface are “dockable” and can be moved around in customized fashion.
- The Hydrograph Window has gone away. We are now using a third-party software object for plotting so hydrographs, the XY Series editor, and other plots are all generated in a separate window. The ability to print, export data, and many other custom display capabilities are available within these plot windows. The user interface within a plot window is accessed by right-clicking in the same way you do for plots in a spreadsheet program like Microsoft Excel.
- Use of GL Graphics. You will notice increased performance and capability in panning, zooming and rotating because of the use of GL. We will also be taking advantage of GL capabilities like transparency in future releases.

Conclusion

WMS continues to be widely used both inside and outside the Corps of Engineers for performing advanced hydrologic and flood plain analyses. The enhancements documented in this paper will help make this more effective and hence the user community more efficient in their modeling activities.